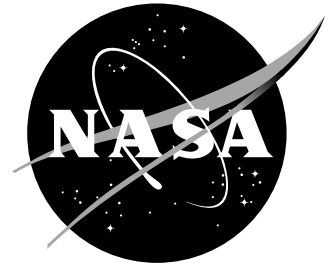


Space Communications Technology Link



A publication which reports upon the news and events of the Space Communications Program
NASA Glenn Research Center • Volume 2, No. 1 • April 1999

Changing the way NASA and the Nation Communicate through Space

Near-Earth Space Internet

James M. Budinger
Space Communications Technology Program Manager
Space Communications Office

Millions of Americans enjoyed the movie "Apollo 13". Both the quality of the production and the inspirational human drama captivated audiences. Near real-time images from the 1997 Mars Pathfinder mission were just as fascinating. Millions of hits on associated Internet sites confirmed our national interest in space exploration through the power of communication.

Glenn Research Center is working to extend the power and ease of commercial terrestrial telecommunications networks, like the Internet, into the near-Earth space environment. For many people, this new capability will open the exploration and experience of space in ways never before possible.

National Space Policy directs NASA to transition to commercial communications services. As part of the recently awarded Consolidated Space Operations Contract, Lockheed Martin Space Operations has envisioned an integrated operations architecture that includes access to spacecraft as readily as accessing a node on the terrestrial Internet is today. Glenn Research Center is developing and demonstrating communications and network technologies that are helping to enable the near-Earth space Internet. Three service categories are envisioned by Glenn Research Center.

The first of the three categories is direct data distribution or D³ (pronounced "D-cubed"). Somewhat like "pay-per-view" movies, D³ services a queued request at the first available opportunity. Commercially provided D³ will make it possible to download a data set from a spacecraft, like the International Space Station, as easily as one can extract a file from a remote server today, using a file transfer protocol. To give an idea of the magnitude of the data transfer possible with D³, information equal to the content of the entire "Apollo 13" movie on digital video disk could be downlinked error-free in less than a minute. Commercial ATM (Asynchronous Transfer Mode) networks would carry the information to end users, such as scientific data to principle investigators, or weather and earth resource imagery to farmers.

In the second category, NASA spacecraft will make use of available commercial services. Some of those services will come from purchasing time on unused transponders that cover land masses. While it is likely there will be gaps in service coverage, and the data rate is likely to be low, Internet services should be available using commercial satellite systems. When available, interactive communications could be established, and stored data could be retrieved from a server on the spacecraft with no apparent difference from browsing the World Wide Web today.

Finally, Glenn Research Center is discussing the future commercial satellite systems in low, medium, and

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(Near-Earth continued.)

geostationary Earth orbits with the U.S. Aerospace companies that are proposing to deploy them. Some of these commercial satellite constellations may be able to communicate directly with NASA spacecraft orbiting below them. Higher data rates, perhaps greater than 100 megabits per second, and smooth contiguous handoffs between satellites, may be possible due to decreased distance between the spacecraft and the commercial relay satellite, and the availability of focused communications links that track all spacecraft within the network.

Glenn Research Center is developing and demonstrating technologies in support of each of these envisioned service categories. Our accomplishments and plans will appear within articles of the *Space Communications Technology Link*.

In the future, it is possible that the features and capabilities of the commercially provided near-Earth space Internet could be extended to the vicinity of Mars. While most of us will probably never travel to the red planet, nor spend a day on the International Space Station, virtual presence made possible by the space Internet could be the next best thing.

For more information please e-mail us at:

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and refer to Article: 2199-01

How Are We Doing?

We encourage your feedback as we continue to develop the Space Communications Technology Link newsletter into a comprehensive Outreach Publication.

Information reported in the S.C.T.L. is the result of work performed by members of both the Communications Technology Division and the Space Communications Office. Together these two organizations influence the success of the entire Space Communications Program.

We would like to hear from you!

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and refer to Article: 2199-02

An in-depth look into our publication:

On our Cover

Interesting facts lead to national interest in "Near-Earth Space Internet".

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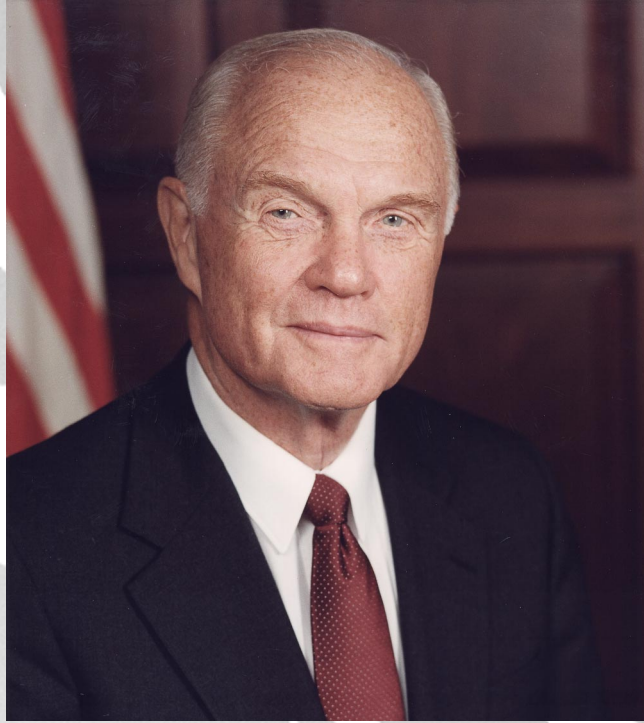
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NASA Center Named After Astronaut John H. Glenn

On October 21, 1998, President Clinton signed an act of law declaring that NASA Lewis Research Center will be designated the John H. Glenn Research Center at Lewis Field. The center name change reflects the well-known astronaut, John Glenn, who was the first American to orbit the earth. Native to Ohio, John Glenn is a supporter of NASA's aeronautics and space research programs. Last October, John Glenn returned to space aboard the Space Shuttle Endeavor where he and his crew conducted experiments associated with the effects of aging as well as three NASA Glenn experiments including Colloidal Disorder-Order Transition (CDOT-2), Colloidal Gelation (CGEL-2), and the Space Acceleration Measurement System (SAMS). Although the renaming of the Center requires many changes, the Center is honored to be named after two great men in space history, John H. Glenn and George W. Lewis. The renaming occurred on March 1, 1999.

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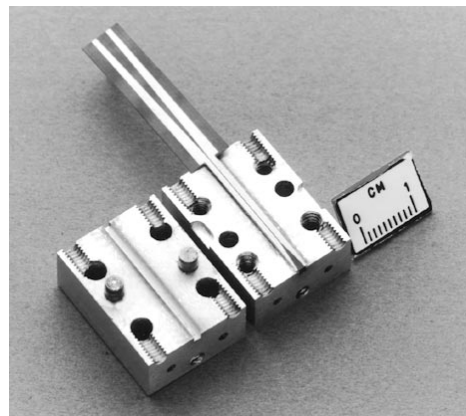
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Linearly Tapered Slot Antenna Radiation Characteristics at Millimeter-Wave Frequencies

Rainee N. Simons and Richard Q. Lee
Applied RF Technology Branch
Communications Technology Division

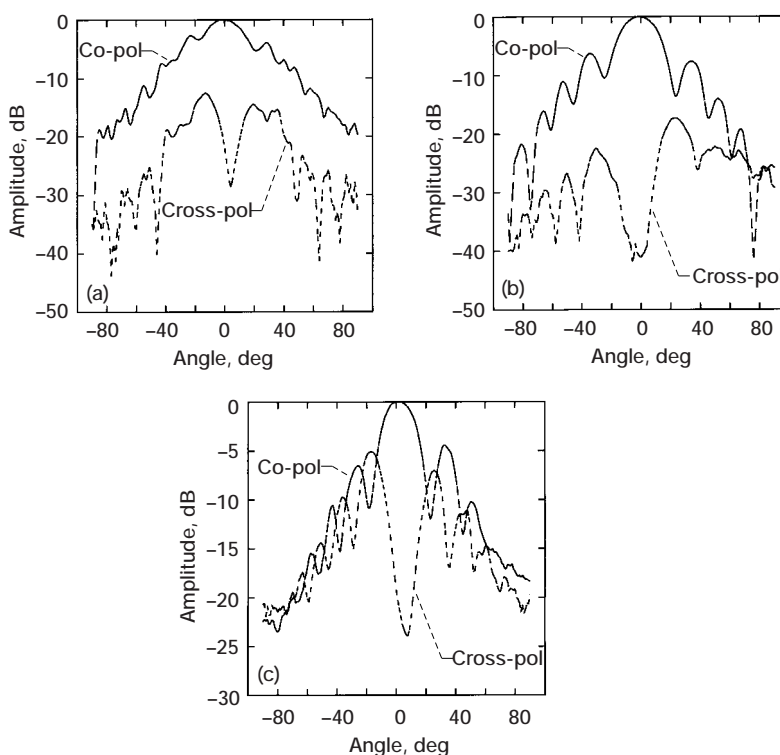
The dimensions of the conventional resonant microstrip patch antenna become very small as the frequency of operation shifts into the higher millimeter-wave (mm-wave) frequency band. This results in increased cost of manufacturing because of fabrication tolerance. In addition, the skin effect conductor losses in the microstrip feed network tend to become excessive, thus lowering the antenna efficiency. An endfire traveling wave antenna, such as a linearly tapered slot antenna (LTSA) (ref. 1), is a viable alternative to a patch antenna at higher mm-wave frequencies. The dimensions of the LTSA are several times the free space wavelength, λ_0 at the frequency of operation which eases fabrication tolerance. In addition, the attenuation due to conductor losses are smaller for a rectangular waveguide which is typically used at mm-wave frequencies in the feed network of LTSA. Lower losses enhances the antenna efficiency.

The LTSA has been extensively characterized in the past by measuring the radiation patterns in the E- and H-planes, beam widths, cross-polarization levels and gain over the frequency range of 8 to 35 GHz (refs. 2 to 4). The LTSA in these experiments are fabricated on a Kapton ($\epsilon_r = 3.5$) and Duroid ($\epsilon_r = 10.0$ and 2.2) substrates. At 35 GHz the LTSAs are excited by a finline-to-rectangular waveguide transition. Some preliminary measurements on imaging arrays at 94 GHz with LTSAs on Kapton substrates as receiving antennas and with biased beam lead diodes soldered at the end of the slots as detectors are reported in references 2 and 5.



LTSA mounted in a split block housing.

This article reports upon the radiation characteristics of LTSA at frequencies of 50, 77, and 94 GHz, which have been recently designated by the Federal Communications Commission (FCC) for several emerging wireless communications. Our studies differ from that in reference 5 in several ways. First, the operating frequency is different. Second, the width W of the ground plane is



Co-pol and cross-pol radiation patterns at 50 GHz. (a) E-plane. (b) H-plane. (c) D-plane.

kept small, about 0.25 to $0.39\lambda_0$, to reduce inter-element spacing in an array. Third, a unilateral finline-to-rectangular waveguide in-line transition is integrated with the LTSA on the same dielectric substrate for loss reduction. Fourth, a sensitive waveguide detector is attached to the finline for detecting the response.

The photo shows the LTSA with integrated slotline-to-finline-to-waveguide transition fabricated on a 5 mil thick RT/Duroid 5880 ($\epsilon_r = 2.22$) substrate. The dimensions of the slotline and finline are determined as explained in reference 6. Three LTSAs are fabricated and their radiation patterns are measured at 50, 77, and 94 GHz respectively. Shown on the previous page are measured co-pol and cross-pol radiation patterns for the E-, H- and D-planes respectively of the LTSA at 50 GHz. Experiments are also under way to measure the feed losses. The LTSA has been experimentally characterized by measuring the radiation patterns at frequencies of 50, 77, and 94 GHz designated for wireless communications. The patterns are well behaved and symmetric. The measured gain of the LTSAs are about 10 dB.

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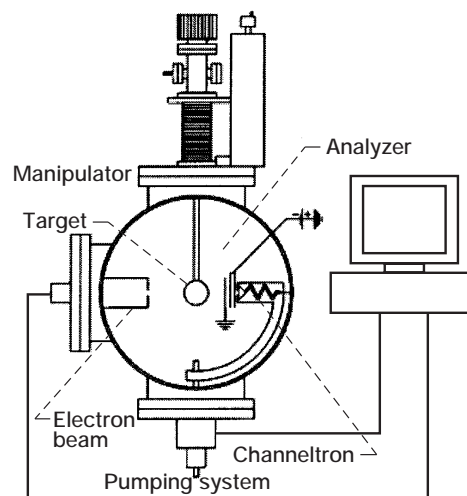
and refer to Article: 2199-04

The Angular Distribution of Elastically Scattered Electrons and its Computed Effect on Collector Performance

Karl R. Vaden and Isay L. Krainsky,
Electron Device Technology Branch
Communication Technology Division

In order to improve the efficiency of traveling-wave tubes (TWT) for space applications, Glenn Research Center has extensively investigated the secondary electron emission of materials for multistage depressed collectors (MDCs).^{1,2} These studies show that the suppression of secondary electron emission significantly improves the performance of MDCs. However, a complete analysis of the effects of secondary electron emission, with respect to collector performance, has not been possible because of the lack of quantitative data on secondary electrons. Secondary electrons are emitted with energies ranging from near zero to the energy of the incident primary. We define elastically scattered secondaries as secondary electrons within 20 percent of the incident energy. Elastically scattered secondaries are of great concern because their energy allows them to follow trajectories that can carry them almost anywhere within the vacuum envelope. If these secondaries leave the collector and reenter the slow wave circuit they can produce undesired signal distortion and oscillation.

The apparatus in the schematic diagram, conceived by Glenn Research Center researchers, was used to obtain



Schematic diagram of the apparatus.

(Continued on page 6)

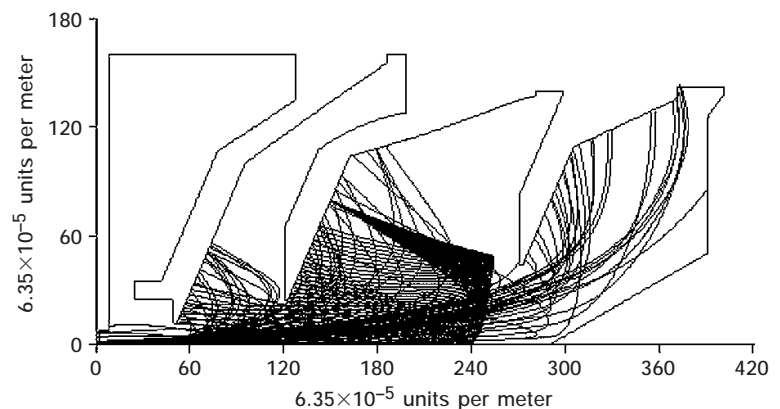
(Angular Distribution continued.)

detailed measurements of the angular distributions of elastically scattered secondary electrons.³ Data was obtained for three surfaces of significant interest to collector applications: polished copper, copper textured by ion sputtering, and isotropic graphite. Analysis of the data showed that these secondaries have a complex angular distribution that is strongly dependent on the atomic number and surface morphology of the target material, as well as the energy and angle of incidence of the incident beam.

At low energies and normal incidence, the majority of the elastically scattered secondaries from the polished copper surface are directed in the direction of the source of the primary electrons (back-scattered). Forward Rutherford scattering increases as the incident angle approaches angles parallel to the target (grazing angles). Forward scattering also increases with primary energy until, at high energies, forward scattering can dominate the angular distributions as the incident angle approaches grazing angle. The majority of the elastically scattered secondaries from ion-textured copper surfaces are back-scattered independent of incident angle or energy. However, the total secondary yield from these surfaces is substantially lower than the total secondary yield from polished copper surfaces. Isotropic graphite has angular distributions very similar to polished copper; however, it also has a much lower secondary yield.

To simplify the large volume of information, the data was modeled with linear combinations of Gaussian and Lorentzian functions. The resultant functions were then used in an interpolation routine to approximate the angular distributions at any arbitrary primary energy or angle of incidence for each material. The complexity and volume of the data did not provide easy incorporation into the traditional codes used for collector modeling. However, recent improvements in computational power and software enhancements now allow the inclusion of the data into previous models of electron beam collectors.

Simulations of a collector designed for a 32 GHz TWT showed that forward-scattered electrons had little impact on the MDC's designed by Glenn Research Center. Back-scattered secondaries were of more concern because those electrons are likely to reenter the slow wave circuit. Because the distributions from ion-textured



Computer model of the back-scattered electrons from one impact site in the collector design for the 32 GHz TWT for the Cassini Mission.

copper surfaces are dominated by back-scattered secondaries, a simulation occurred in which a collector, built from copper, textured by ion sputtering. A detailed model of the collector showed approximately one percent of the primary beam current returned to the slow wave circuit, which is in agreement with experimental observations. The figure below shows a sample of such a model. With respect to the effects of secondary emission upon MDC performance, isotropic graphite is the most attractive material because it exhibits low yield and little back-scattering. The newly available angular distributions of elastically scattered secondaries and their application to collector modeling have allowed even more accuracy and insight to MDC modeling and design.

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and refer to Article: 2199-05

Space Communications...

...We're Out There.

Satellite Telemammography at the Radiological Society of North America (RSNA) Annual Meeting

*Robert J. Kerczewski
Satellite Networks and Architectures Branch
Communications Technology Division*

The Radiological Society of North America (RSNA) Annual Meeting is the largest medical conference in the world, attended by more than 60,000 physicians, technicians, researchers, administrators and industry representatives from all over the world. The conference, held at Chicago's McCormick Place during the first week of December, 1998, was attended by NASA representatives Bob Kerczewski, Paul Mallasch, and Brian Kachmar. Major medical imaging equipment manufacturers such as Siemens, GE, Picker, Trex, NEC, etc. secure 50% or more of their annual sales during this one-week event.

The growing acceptance of telemedicine as "way of life" for interconnecting far-flung networks of medical facilities and newly merged medical conglomerates was apparent in the large number of exhibits, displays, and seminars on the subject. Also evident was an increasing number of collaborations between industry and medical institutions in creating new telemedicine applications. The emerging DICOM (Digital Imaging and Communications in Medicine) standard, vital for enabling interoperability across telemedicine networks, is gaining ground in both industry application and user acceptance. This increases the urgency for studying and improving DICOM's performance over satellite links.

Physicians discussed the need to connect small remote facilities with major medical campuses allowing for the capability to perform image-based diagnosis from home, addressing the excess costs and general unavailability of terrestrial communications links in the U.S., as well as in less-developed countries.

However, the awareness of the capabilities of satellite communications to provide low cost, efficient telemedicine links remains relatively low. Hence, Glenn Research Center's exhibit on telemammography using satellite communications received more than 250 visitors interested in various technologies associated with



Robert Kerczewski of NASA Glenn Research Center's Communications Technology Division shakes the hand of the "InfoRad Village" Mayor at RSNA Conference in Chicago, Illinois.

telemammography, teleradiology, application of image compression, and satellite and other communications methods. In addition to the Space Communications Program exhibit, about 200 interactive displays and exhibits were present representing industry, academia, medical, and government research organizations. The NASA exhibit has also generated positive publicity by attracting the interest of several trade journal reporters. As a result, the article titled "Digging in at RSNA", was published in the journal "ADVANCE for Administrators in Radiology & Radiation Oncology". Articles for publications in two other periodicals are pending.

NASA's exhibit was included in the RSNA's "InfoRad Village", a sort of theme park for conference attendees to learn about new computer-based radiology methods and technologies. The 1890's-themed InfoRad Village came complete with a village square and a top-hatted, hand-shaking village mayor. As the Inforad "theme song" performed in the distance, mimes and jugglers strolled the town.

A growing acceptance of applying lossy image compression techniques to reduce the time and cost of transmitting radiological images over telemedicine links is being

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(Satellite Telemammography continued.)

acknowledged. NASA and the Cleveland Clinic are helping to dispel the myth that lossy compression would negatively impact the visual quality, and hence diagnostic accuracy, of digital medical images by studying the diagnostic accuracy of compressed digital images transmitted over satellites.

Mammography remains the most challenging radiology application to be performed over telemedicine links in general, and over satellite links in particular. The necessity for continued research and development to enable low-cost and clinically acceptable satellite telemammography to reach the millions of women in need of such services is a primary conclusion from NASA's participation at the 1998 RSNA Meeting. The need to generate positive clinical research results and to continue to improve the interoperability of satellite links in the telemedicine environment will also be important to the eventual deployment of satellite based telemedicine for both terrestrial and space applications.

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Spacecom@grc.nasa.gov

and refer to Article: 2199-05

Global Positioning System (GPS)-Protection of Radio Spectrum Supporting the Global Navigation Satellite System (GNSS)

*James E. Hollansworth
Spectrum Management Branch
Space Communication Office*

NASA, National Oceanographic Atmospheric Administration, Federal Aviation Administration, United States Coast Guard, United States, Industry Council, and the Air Transport Association have joined together to form the International (GPS) Outreach Committee of the U.S. Government to protect spectrum used by the Global Positioning System (GPS) from encroachment by future mobile satellite services. This group prepared an information booth on GPS that appeared at the International

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Telecommunications Union Plenipotentiary'98 Technology Demonstration at Minneapolis, Minnesota and most recently the Pacific Telecommunications Conference at Honolulu, Hawaii, explaining the uses and benefits of GPS in the World.



GPS display featuring Satellite Navigation at PTC '98 in Honolulu, Hawaii.

The primary intent of the information booth is to describe the need to retain the 1559-1610 MHz band for exclusive use by the Aeronautical Radionavigation Service (ARNS) and the Radionavigation Satellite Service (RNSS). GPS applications that use this portion of the radio frequency spectrum include aviation, agriculture, environmental, maritime, public safety, rail, recreation, space, surface, surveying and timing.

At the 1995 International Civil Aviation Organization (ICAO) COM/OPS Divisional Meeting, the frequency band 1559-1610 MHz was identified as the sole band available to satisfy the current and future spectrum requirements of the GNSS. Both the U.S.(GPS) and the Russian Federation's Global Navigation Satellite System (GLONASS)—the constituent elements of the GNSS—operate in this band, and GNSS augmentations are planned to operate in this band.

INMARSAT submitted a proposal at The World Radio Conference-97 (WRC-97) to introduce Mobile Satellite Services (MSS) at the lower end of the 1559-1610 MHz band, specifically from 1559-1567 MHz. WRC-97 delayed any action on this request until WRC-00. The proposal, International Telecommunications Union (ITU) Resolution 220, "On the Feasibility of Making Allocations for MSS (space-to-Earth) in the Band 1559-1567 MHz,"

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subsequently was withdrawn, but may resurface. The issue is on the WRC-00 agenda. The experience of the international civil aviation and space communities in other bands shared between aviation/space and non-aviation/space users has raised significant concern that there could be two impacts if this proposal is approved: (1) radio frequency interference cases in the GPS spectrum could increase and, as a result, (2) future GNSS growth would be constrained.

The U.S. Government has proposed that a new allocation be made to the bands 1215-1260 MHz and 1559-1610 MHz for space-to-space GPS use, NASA's Space Shuttle fleet, The International Space Station, and many experimental and commercial satellites are equipped, or soon will be equipped, for GPS. Additionally, many countries that are currently in the space business and those that are planning to enter expect to use GPS as one of the key guidance tools.

It is expected that the addition of a radionavigation satellite service (RNSS) allocation, encompassing the new GPS civil signal, will be set for 1176 MHz. This will result in expanded, more robust, service which will be available for public use.

GPS is a one-way receive-only broadcast at 50 bits per second. In contrast two-way communications transmissions that usually transmit voice and data at 2400 bps+. This goes to the heart of the question posed by ITU Resolution 220: Is it feasible for GPS (ARNS/RNSS) to share the same frequency allocation on a co-primary basis with MSS? Because of the very low power and bit rate of the receive-only GPS signal, other communications systems using its frequency band easily can compromise the "continuous worldwide availability" of GPS. Several technical analyses conclude that "sharing" of the RNSS/ARNS spectrum is not possible and recommend that member states should not support any proposal for GPS to share its band of 1559-1610 MHz with any other type of communication system, in order to protect present and future GNSS applications.

...We're Out There.

The draft Conference Preparatory Meeting (CPM) text relative to sharing in the space-to-Earth direction says "Studies conducted in the International Telecommunications Union Radio Bureau (ITU-R) indicate the incompatibility of the MSS (space-to-Earth) and ARNS/RNSS in any portion of the 1559-1567 MHz band." Draft elements for CPM-99 (ITU document 8D/149E) state "Through a combination of ("a number of erroneous assumptions about the GPS system, behavior of the spread spectrum codes and GPS receivers" and "critical factors about interference to GPS receivers...not considered") and other factors, the INMARSAT study severely exaggerated the amount of interference that can be tolerated by receivers in the GPS system." In order to protect the viability and robust use of GNSS by all the people of the world, the present and future requirements of the multitude of radionavigation satellite service applications require that the 1559-1610 MHz band be protected from interference, for exclusive use by ARNS and RNSS.

The draft CPM text for the Space-to-Space allocation will most probably include two options, one of which is unacceptable to the space community. The unacceptable option would allow new RNSS systems in the bands without regard to potential adverse impact to existing space operations.

No draft CPM text has been developed at this point for the third civil signal, however, due to the nature of the existing allocation for exclusive ARNS use, and since the signal will be of primary benefit to the aviation user community, major opposition to the allocation is not anticipated.

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and refer to Article: 2199-06

Space Shuttle Program Recognizes Notable Contribution

Janice L. Zarrelli
ADF Corporation
Space Communications Program Outreach



James Hollansworth

On November 23, 1998, the Space Shuttle Program recognized Spectrum Advocacy Program Manager, James Hollansworth, by presenting him with an award that exemplifies his significant contributions toward improving the regulatory protection of vital 2 Ghz communication frequencies, utilized by the Space Shuttle Program and other NASA space flight programs. The award was signed by William F. Readdy, Deputy Associate Administrator (Space Operations), Office of Space Flight. In addition to this award, Hollansworth received a VIP invitation to watch the launch of John Glenn aboard the Space Shuttle Endeavor on Mission STS-88.

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and refer to Article: 2199-07

Space Comm Outreach Team Member Earns Accreditation

John J. Mudry
Manager, Outreach Projects
Space Communications Office



Jennifer Sibits

The Universal Accreditation Program, managed by the Public Relations Society of America (PRSA), has awarded accreditation to Jennifer J. Sibits, Outreach and Public Relations Manager of the Space Communications Program with ADF Incorporated located in Cleveland, Ohio.

The Universal Accreditation Program seeks to improve the practice of public relations by awarding the designation Accredited in Public Relations (APR) to public relations professionals who successfully complete an examination that measures knowledge, experience, and professional judgement.

"Practitioners who achieve this credential demonstrate a commitment to their companies, their clients and their profession", said Christine Gronkiewiz, APR, chair of the Universal Accreditation Board, and Director of Media Relations Strategy for Ameritech Corporation.

Universal Accreditation is a voluntary certification program for public relations professionals who have at least five years of paid, full-time experience in the professional practice of public relations, or in teaching or administration of public relations courses in an accredited college or university. The program was formed in January of 1998 is represented by over 6,000 accredited public relations practitioners. The examination is administered by the Public Relations Society of America (PRSA), which operated its own Accreditation program beginning in 1964.

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Space Communications...

...We're Out There.

Space Communications Employees... On The Move

Janice L. Zarrelli
ADF Corporation
Space Communications Program Outreach



James Budinger

James Budinger was named to the position of Space Communications Technology Program Manager in the Space Communications Office on August 30, 1998. Budinger began his career at Glenn Research Center 22 years ago as a Cleveland State co-op student. He brings to the position expertise in digital electronics and satellite communication systems and technologies. He previously served as Deputy and Acting Chief of the Digital Systems Technology Branch and Acting Chief of the Project Development and Integration Office. In his new position, Budinger will lead Glenn Research Center's Space Communications Program transition within the Agency's Cross-Enterprise Technology Development Program.



Dr. Charles Raquet

Presently serves as Chief Engineer of the Communications Technology Division at Glenn Research Center. Raquet's responsibilities as Chief Engineer include supporting program technology planning and evaluation activities. Prior to this position, Raquet served as Chief of the Antenna & RF Technology Branch. His branch was responsible for the successful development and demonstration of several antenna concepts, components and systems, most notably Ka-band MMIC arrays. Raquet has over 19 years of experience in satellite communication technology and has been with Glenn Research Center for over 31 years.



John Mudry

In addition to responsibilities associated with ISO 9001 Certification, the Advanced Communications Technology Satellite (ACTS) Customer Liaison activities, and program performance assessment, John Mudry has assumed the responsibilities of Outreach Project Manager for Glenn Research Center's Space Communications Program (SCP). Mudry is an experienced member of the SCP Outreach team and will work with both SCP staff and the Aerospace Design and Fabrication (ADF) contractor staff, lead by Jennifer Sibits, to create and deliver an Outreach campaign which communicates the vision, mission, goals, activities, and accomplishments of the Space Communications Program. This Outreach activity will serve to inform a wide variety of audiences including the general public, government, and the technical communications community. The Space Communications Technology Link (SCTL) newsletter is one of several SCP Outreach products and services. Mudry has been associated with Glenn Research Center for 19 yrs. and with the Space Communications Program since August, 1996.

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Spacecom@grc.nasa.gov

and refer to Article: 2199-9

ACTS Solar Array and Battery Performance

*Don R. Hilderman
ACTS Experiments Office
Space Communications Office*

The Advanced Communications Technology Satellite (ACTS) is a NASA experimental satellite communication system designed to demonstrate on orbit Ka-band communications and switching technologies that will be used by NASA and the commercial sector in the 21st century. To conduct the required experimental operations, six satellite subsystems are used aboard the spacecraft to supply communications and maintain a healthy and stable satellite platform in geosynchronous orbit. The six subsystems are the thermal subsystem, attitude control subsystem (ACS), multibeam communications package (MCP), command, ranging and telemetry (CR&T), reaction control subsystem, and the power subsystem.

The challenge to all satellite manufacturers is to design and build satellites that will reliably operate in the harsh space environment for many years. During the five year ACTS experiments program, spacecraft engineers from Lockheed Martin Astro Space have successfully maintained and operated all ACTS subsystems. This article concentrates on the performance of the solar arrays and batteries used in the ACTS power subsystem during the past five years on orbit.

The ACTS solar array contains four planar solar panels, two on each side of the spacecraft for a total area of 144 square feet. High efficiency N-on-P, 2×4 cm solar cells are bonded to a Kevlar facesheet which is bonded to 1 in. thick aluminum honeycomb core panel. The solar cells are electrically connected to each other with custom cut silver mesh and wire.

Solar array electrical performance data was collected after five years of on-orbit experiments and compared with performance data after launch. Available power output of the solar array was measured to be 1842 Watts

beginning-of-life in September 1993. Spacecraft telemetry measurements as of December 1998 indicate that total solar array output power measured approximately 1650 watts. This represents a ten percent drop in available solar power and is considered normal, acceptable, and within design margins. Solar array power reduction during the past five years is due to solar cell and solar cell cover glass degradation caused by exposure to charged particles and radiation in geosynchronous orbit.

ACTS uses approximately 1100 Watts of electrical power to operate all six electrical subsystems. Most of the excess 550 Watts (1650 W- 1100 W) that was generated by the solar arrays and not used by the six electrical subsystems needs to be reduced or shed as excess heat. One method used is through a bank of shunt resistors in the thermal subsystem that serve to dissipate and remove excess electrical power generated from the spacecraft solar arrays.

The primary method used to reduce excess electrical power generated by the solar arrays is to tilt the solar array panels slightly away from the sun. This reduces the solar energy collected and electrical energy generated. ACTS solar arrays have been canted or turned approximately 40 degrees away from the sun during the entire experiments program to help reduce the excess power. Not all of the 550 Watts is dissipated in the shunts or reduced by tilting the solar arrays. Approximately 50 Watts is held in reserve to provide margin for transient loads within the six electrical subsystems while maintaining 35.5 Volts across the two batteries.

The primary purpose of the ACTS batteries is to provide electrical power to the six electrical subsystems during solar eclipse periods. ACTS contains two independently charged, 19 ampere-hour nickel-cadmium batteries. Each battery contains 22 independent cells connected in series for a nominal voltage of 33 Volts per battery. The two batteries are connected in parallel for a total battery capacity of 38 Ampere-hours. During 100% sunlight periods, the batteries are trickle-charged at a constant C/60 rate (0.32 Ampere per battery). The letter "C" represents nameplate capacity for one battery of 19 Ampere-hours. Immediately after eclipse, each battery is charged at a constant rate of C/20 (0.95 Amperes)



for a period required to reach full charge.

The batteries have been working so well over the past five years that battery reconditioning is considered unnecessary by spacecraft controllers. The purpose for reconditioning each battery is to remove any "memory effect" on the battery cells resulting from minimum use during 4.5 months of continuous sunlight and charging between eclipse seasons. Battery "memory effect" is the tendency for the battery voltage not to provide the original power capacity during charging. Each battery has a reconditioning circuit to execute a deep discharge/rapid recharge on each cell in a battery shortly before each eclipse season. Battery "memory effect" has not been observed during the past five years resulting in no reconditioning.

The excellent ACTS battery performance to date is due in part to the spacecraft controllers at Lockheed Martin Astro Space that manage all command and telemetry operations during the past five years of experiments. Engineers have successfully controlled the spacecraft temperatures, loads and discharge rates prior to, during and after eclipse to reduce potential battery stress. Spacecraft battery depth of discharge during eclipse periods has not exceeded 38% with a battery voltage no lower than 25.8 Volts and a temperature no greater than 23 °C. Overstressed batteries occur when depth of discharge exceeds 50 percent, battery voltage falls below 24 Volts or temperature rises above 25 °C. The voltage difference between the highest battery cell and the lowest cell (cell divergence) has never exceeded 0.039 Volts. Battery reconditioning is recommended when cell divergence exceeds 0.05 Volts.

ACTS power subsystem battery and solar array performance are forecasted to provide reliable and successful experiment operations through the scheduled conclusion of ACTS in September 2000.

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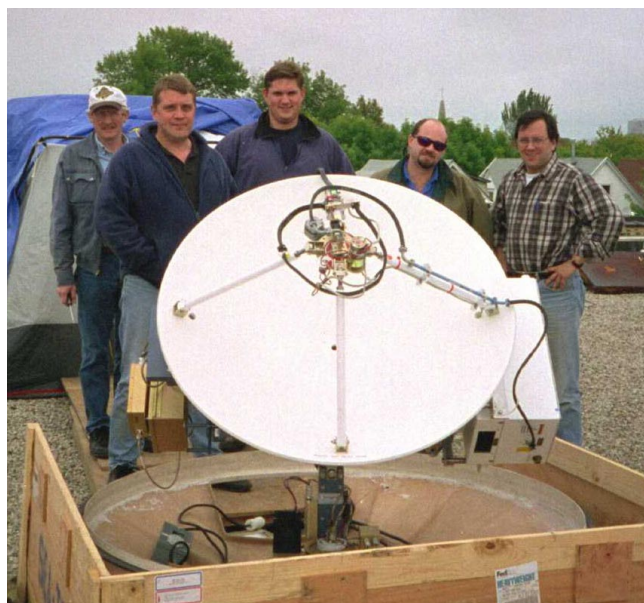
Milestone NRL/NASA Experiment Demonstrates Unprecedented Data Transmission Rates

*Janice Shultz
Public Affairs,
Naval Research Laboratory*

This article first appeared in the December 21, 1998 issue of Labstracts, Naval Research Laboratory

During a record-breaking demonstration of a Ka-band, two-way satellite communications link, scientists from NRL, Glenn Research Center, and their industry partners achieved an unparalleled data rate transmission of 45 megabits per second (Mbps) between a moving vessel at sea and a fixed-Earth station. Previously, the highest demonstrated ship-to-shore satellite data rate was 2 Mbps.

A series of tests conducted in October on southern Lake Michigan, near Chicago, using NASA's Advanced Communications Satellite (ACTS), clearly illustrate the viability of high data rate (HDR) Ka-band systems for



Preparing the satellite dish for testing, project members (from left to right) Rich Groh, Doug Hoder, Greg Romaniak, from NASA's Glenn Research Center; Wes Schenk, from Sea-Tel, Inc.; and Mike Rutar, NRL principal investigator

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(Milestone Experiment continued.)

ship-to-shore communications. High data rates will open new applications for both Navy communications and civilian users of mobile satellite systems and services.

Using current technology, the Navy cannot link HDR shipboard local area networks (LANS) to terrestrial networks at comparable HDR speeds while ships are away from port. NRL now has programs underway to develop and demonstrate techniques to enable HDR wide area network satellite and wireless connectivity from ships, and HDR satellite communications are a critical component of many of these programs. The objectives of this experiment focused directly on significant elements of HDR mobile networking, in this particular case ship-to-shore, that address this current DoD requirement.

Ultimately, small-deck combatants such as destroyers and frigates outfitted with similar equipment could benefit from the same meteorological and oceanographic data currently received by carriers, cruisers, and other large-deck combatants. The faster data transmission rate will also permit small-deck vessels to receive teletraining along with their large-deck counterparts and make teleconferencing technology available for interactive planning, crisis management, and telemedicine.

The NRL-NASA Shipboard ACTS Ka-band Experiment (SHAKE) provided at least 20 times greater data rate than the current shipboard standard, demonstrating data rates of 45 Mbps and user applications (file transfers, video teleconferencing) data rates of above 40 Mbps, significantly higher than the current 1.5 Mbps of 64 Kbps standards. While future Navy systems may not require 45 Mbps to a single platform, it is likely data rates in the 1-2 Mbps range, with the ability to increase as required, will be required on a larger number of ships and combatants than is currently available today.

The NRL and NASA SHAKE researchers conducted other experiments concurrently with the data rate transmission trials, including:

- TCP/IP file transfers, which would permit the high speed transfer of imagery, strategic and tactical theater information to and from Navy ships. This data transfer technique is also applicable to a host of NASA spacecraft in near-Earth orbit that routinely transmit data from space to ground using Geostationary relay satellites. Data transfer tests were



Shipboard terminal equipment rack.

conducted in disk-to-disk, disk-to-tape, and tape-to-disk configurations

- Video and voice technologies for real-time video and voice delivery. These technologies can be used for video conferencing, crisis response, telemedicine, mentoring, education, telephony, and entertainment
- Tracking performance testing of the current system in a Ka-band with the satellite in an inclined-orbit environment was evaluated

The final goal of this work, says NRL principal investigator Mr. Mike Rugar, is to support the use and understanding of emerging Ka-band satellites and services to fulfill emerging HDR Naval satellite based networking requirements. Understanding how emerging satellite services can best be used to meet Naval requirements and how the Navy can best be positioned to use these emerging services is a critical component of this work. Underlying networking, protocol, terminal, and bandwidth-on-demand issues, combined with variable bit rate service

and HDR capabilities, present challenges not typically addressed in current Naval SATCOM systems, notes Rupar.

Mr. Louis R. Ignaczak, Chief, ACTS Experiments office notes, "With today's pressure of shrinking resources, rapid advancements in technology, and the pursuit of relevant communication architectures for one's mission, it is becoming extremely important to collaborate on synergistic endeavors and leverage unique opportunities-it seems to be a natural fit for NASA and NRL to jointly promote technology that benefits the Nation as a whole."

Supported by the Office of Naval Research, participating industry organizations included: Infinite Global Infrastructures, Chicago, Illinois; Sea-Tel, Inc., Concord, California; Hill Mechanical Group, Chicago; FORE Systems, Pittsburgh, Pennsylvania; Xicom Technologies, Santa Clara, California; Raytheon Marine Company, Manchester, New Hampshire; and Comsat Laboratories, Clarksburg, Maryland. Additional information can be obtained at: <http://mrpink.grc.nasa.gov/shipboard>.

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Spacecom@grc.nasa.gov

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Advanced Aviation Communication Architecture Development Study

*Steven W. Mainger
Satellite Networks and Architectures Branch
Space Communications Office*

What aviation communication systems will make our skies safer and air travel more efficient in the future; oh, let's say, in the year 2007 or even 2015?

This question is the challenge facing the Advanced Air Transportation Technologies (AATT) and Aviation Weather Information (AWIN) Communications project teams. To help meet this challenge, the teams released a combined research task order on January 11, 1999 to solicit several aerospace contractors to bid for the chance to examine the present aviation communications systems and speculate on the aviation communications architecture of the future.

The plan for developing a vision of the future begins by examining the present aviation communication systems (ACS) and facilities, capturing the generic communications requirements and using those requirements to construct several concepts of the future; to the year 2015 for air traffic management, and 2007 for aviation weather information. The potential bidders were asked to first identify and prioritize the user needs for both air traffic management (ATM) and weather information dissemination applications; then, to develop the communications system functional requirements from identified user needs. These functional requirements will lead to determining the actual communications system engineering requirements. Using these engineering requirements, a number of preliminary candidate architectural concepts will be developed. These concepts will hopefully capture the fundamental elements that will change the face of any future system. The candidate concepts will then be assessed by a joint government/industry team and a single concept for the 2015 state will be selected for future detailed definition/development. Once mutually agreed upon, the selected concept will be developed into a detailed, comprehensive communication system architecture for the 2015 state. From that end (2015) state architecture, the vision will then proceed back towards the year 2007, which is the mid-point for the ATM system and the target year for the AWIN team and for the weather information dissemination architecture. The AWIN team seeks to capture an advanced communication and information technology architecture that enables the timely dissemination of high quality aviation weather information to all relevant users. It is thought by working in reverse form the desired architecture, the critical elements of the ACS of today are identified. Steps can be recommended to channel resources and development efforts into systems that have a future and gracefully phase-out systems that have little to contribute to that future vision.

From this study, the AATT and AWIN teams hope to get an architecture of aviation communications that will provide much needed direction for the development of aviation communication systems that work in concert to coordinate our nation's skies; that provide air crews high quality, usable weather and air traffic information; and airline passengers with the latest stock market quote, phone calls from home or a the latest block buster movie.

Contractor proposals are expected to occur mid-February. The AATT and AWIN teams will have the

(Continued on page 16)

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(Advanced Aviation Communication continued.)

authority to choose the best candidate from among renowned corporations.

Ahh, the future! If only you had a crystal ball; the future awaited but a glance—we'd expect you to write up a proposal.

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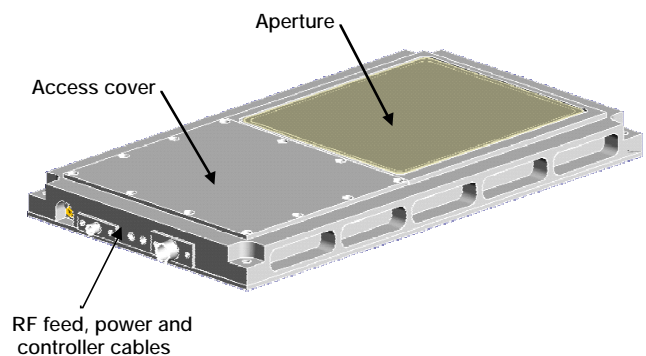
Advanced Antenna Technology for Aeronautical Communications

Robert J. Zakrajsek
Applied RF Technology Branch
Communication Technology Division

The goal of the Advanced Communications for Air Traffic Management (AC/ATM) project is to enable a communications infrastructure that provides the capacity, efficiency, and flexibility necessary to realize the mature Free-Flight environment. The technical thrust of the AC/ATM Project is targeted at the design, development, integration, test and demonstration of enabling technologies for global, broadband aeronautical communications. Since Ku-Band facilities and equipment are readily available, one of the near-term demonstrations involves a link through a Ku-Band communications satellite.

This month's update will be on the antennas that support the initial AC/ATM communications links. Both of these antennas utilize Monolithic Microwave Integrated Circuit (MMIC) amplifiers and phase shifters to electronically steer the antennas. This link is asymmetrical with the downlink to the aircraft (mobile vehicle) at a throughput rate of greater than 1.5 megabits per second (Mb/s), while the throughput rate of the uplink from the aircraft will be greater than 100 kilobits per second. The data on the downlink can be narrow band, wide band, or a combination of both depending on the requirements of the experiment. The AC/ATM project is developing a phased array Ku-Band transmit antenna for the uplink from the test vehicle. Many Ku-Band receive antennas have been built and one will be borrowed for a short time to perform the initial experiments.

The Ku-Band transmit antenna is a 254 element MMIC phased array antenna being built by Boeing Phantom Works. Each element is capable of radiating over 100 milliwatts. The size of the antenna is approximately 43 cm by 24 cm by 3.3 cm thick. The antenna can be steered beyond 60 degrees from broadside. The beamwidth varies from 6 degrees at broadside to 12 degrees at 60 degrees, which is typical of phased array antennas. When the antenna is steered to 60 degrees, that beamwidth will illuminate approximately five satellites on the orbital arc. In order to avoid interfer-



Boeing 254 Element Ka-Band Phased Array Transmit Antenna.

ing with the adjacent satellites, spread spectrum techniques will be utilized to keep the power impinging on the adjacent satellites below the noise floor of those satellites. This antenna is power limited. If the antenna elements are increased by a factor of four (1024) or sixteen (4096) the gain will increase and the beamwidth will decrease in proportion. For the latter two antenna sizes, the power must be "backed off" to prevent interfering with the neighboring satellites. The receive antenna is composed of 1500 phased array elements with an approximate size of 60 cm by 90 cm by 3.5 cm thickness.

The System Phased Array Controller (SPAC) can control both a 1500 element receive and a 500 element transmit antenna. For ground testing the controller will allow manual beam pointing and polarization alignment. For normal operation, the system can be connected to the receive antenna and the navigation system for real-time autonomous track operation. This is accomplished by first pointing both antennas at the satellite using information from the aircraft data bus. The SPAC will then electronically adjust the antenna pointing of the receive

antenna to find the peak signal. After the peak signal has been found, the transmit antenna's beam will be pointed to the same steering angles as the receive antenna. For initial ground testing without an aircraft, the ARINC 429 data bus will be simulated by a gyro system purchased for a previous project.

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and refer to Article: 2199-13

The Role of the Dynacs Team in the Direct Data Distribution (D³) Project

*Thomas J. Kacpura,
Team Lead, D³ Project
Dynacs Engineering*

*Lawrence W. Wald,
Project Manager, D³ Project
Space Communications Office*

This article describes the role of the team from the Dynacs Engineering Company in support of the Direct Data Distribution (D³) project. The D³ project is a team effort composed of several organizations; the Glenn Research Center's Space Communication Office (SCO), the Glenn Research Center's Communications Technology Division (CTD), the Glenn Research Center's Office of Safety, Environmental, and Mission Assurance (OSEMA), the Raytheon System Company, and Dynacs. Raytheon is providing the phased array antenna assembly, the CTD is providing the digital encoder modulator system and the ground terminal, the SCO provides overall management of the project, OSEMA provides Safety and Mission Assurance oversight, and Dynacs will provide the overall design, development, integration, test, and evaluation for D³. Dynacs will also be responsible for the integration, testing, and documentation required to fly the payload on the Space Shuttle.

The Space Science Department of Dynacs has extensive experience with various Glenn Research Center's organizations in the design, development, integration, and mission support of both microgravity and technology

...Project Updates.

payloads. The payloads have been flown on various carriers such as the KC-135 reduced gravity airplane, Glenn Research Center's sounding rockets, and the Space Shuttle. Dynacs is also currently involved in the development of payloads for the International Space Station. A cadre of experienced engineering and technical professionals has been drawn from previous flight projects to provide the support necessary for the D³ project.

The D³ project is currently in Phase B, also known as the conceptual development phase. The Dynacs team is currently engaged in four engineering tasks as follows: (1) a feasibility study of the overall approach for D³, (2) a pointing and tracking study, (3) development of preliminary interface specifications, and (4) a preliminary safety assessment. Currently the main engineering concern is the pointing and tracking requirement, which requires precise pointing of the array from the Space Shuttle to the ground station, while simultaneously pointing the ground station dish antenna at the Space Shuttle. The initial indication from the study is that the link can be made between the ground terminal and the flight payload, although more information is needed regarding the Space Shuttle attitude and position accuracy.

From a logistics view, the preliminary safety assessment of the effects of RF transmitted by the array in the Shuttle cargo bay may require design and operational considerations for the payload. Dynacs and OSEMA personnel have conducted preliminary discussions with both Goddard Space Flight Center (GSFC) and Johnson Space Center (JSC) personnel regarding the possible hazards of operation within the Space Shuttle. The project requires additional information and support from GSFC and JSC personnel in the areas of payload definition and mission integration. This support will be forthcoming once the payload has been approved for spaceflight (manifested) by NASA Headquarters. Upon the approval for spaceflight the preliminary interface specifications will be completed and documented, the pointing and tracking study completed, and the overall feasibility for the experiment validated. The preliminary safety assessment will lead to the Phase 0/1 Flight Safety Review, planned for the 3Q of FY99 at JSC. The Phase B effort will culminate with the Preliminary Design Review, currently planned for the 1Q of FY00.

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NASA/SCP Embarks on Reimbursable Space Act Agreement with INTELSAT

Jennifer J. Sibits
ADF Corporation
Space Communications Program Outreach

NASA Glenn Research Center and the International Telecommunications Satellite Organization (INTELSAT) have entered into a reimbursable Space Act Agreement to conduct demonstrations comparing Ka-band and Ku-band based communications systems. The demonstration provides an opportunity to compare interactive, multi-media services such as ISDN telephony and video, MPEG video, internet access, and file transfers using conventional (Ku-band) and next generation (Ka-band) technologies. NASA's Space Communications Program will provide the Ka-band system and application demonstration capability using three Ultra Small Aperture Terminals (USAT), the Advanced Communications Technology Satellite (ACTS), and a variety of application equipment. Like INTELSAT, U.S. satellite service providers and their user community stand to gain from the extended operations of the ACTS spacecraft.



USAT: Ultra Small Aperture Terminal.

Communications Technology

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For more information please e-mail us at:

Spacecom@grc.nasa.gov

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Space Communications Program

Space Communications Office

Mr. Pete A. Vrotsos
Manager, Space Communications Office
Pete.A.Vrotsos@grc.nasa.gov 216.433.3560

**Space Communications Technology
 Program Manager**
 Mr. James M. Budinger
James.M.Budinger@grc.nasa.gov 216.433.3496

ACTS Experiments Office
<http://acts.grc.nasa.gov>
 Chief, Mr. Louis R. Ignaczak
Louis.R.Ignaczak@grc.nasa.gov 216.433.6607

Spectrum Management Branch
 Chief, Mr. Wayne A. Whyte, Jr.
Wayne.A.Whyte@grc.nasa.gov 216.433.3482

Projects Development and Integration Branch
 Chief, Ms. Denise S. Ponchak
Denise.S.Ponchak@grc.nasa.gov 216.433.3465

Advanced Communications Technology Satellite (ACTS)
 Project Manager, Mr. Robert A. Bauer
Robert.A.Bauer@grc.nasa.gov 216.433.3431

**Advanced Communications for Air Traffic
 Management (AC/ATM)**
Advanced Weather Information Network (AWIN)
 Project Manager, Mr. Konstantinos S. Martzaklis
Konstantinos.S.Martzaklis@grc.nasa.gov 216.433.8966

Direct Data Distribution (D³)
 Project Manager, Mr. Lawrence M. Wald
Lawrence.M.Wald@grc.nasa.gov 216.433.5219

Communications Technology Division

Dr. W. Dan Williams
Chief, Communications Technology Division
Wallace.D.Williams@grc.nasa.gov 216.433.3500

**Chief Engineer of Space Communications
 Program and Communications Technology**
 Dr. Charles A. Raquet
Charles.A.Raquet@grc.nasa.gov 216.433.3471

Satellite Networks and Architectures Branch
<http://ctd.grc.nasa.gov/5610/5610.html>
 Chief, Dr. Kul B. Bhasin
Kul.B.Bhasin@grc.nasa.gov 216.433.3676

Electron Device Technology Branch
<http://ctd.grc.nasa.gov/5620/5620.html>
 Chief, Dr. Vernon Heinen (Acting)
Vernon.O.Heinen@grc.nasa.gov 216.433.3245

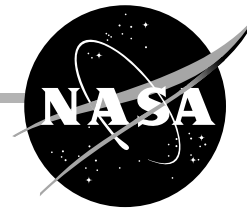
Applied RF Technology Branch
<http://ctd.grc.nasa.gov/5640/5640.html>
 Chief, Mr. Richard R. Kunath
Richard.R.Kunath@grc.nasa.gov 216.433.3490

Digital Communications Technology Branch
<http://ctd.grc.nasa.gov/5650/5650.html>
 Chief, Mr. Gene Fujikawa
Gene.Fujikawa@grc.nasa.gov 216.433.3495

Commercial Communications Program

Mr. James W. Bagwell
Chief, Commercial Communications Program
James.W.Bagwell@grc.nasa.gov 216.433.3502

Space Communications Technology Link



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Telecommunications has become an integrated part of everyday life. With the explosion of communications capabilities and the rise of the "Information Age" it is more important than ever that students understand the fundamentals of telecommunications in order to stay competitive in a world driven by the need to communicate quickly, reliably and globally. We are pleased to announce a brand new NASA educational series on telecommunications, brought to you by the NASA Glenn Research Center Space Communications Office, with assistance from the NASA Glenn Learning Technologies Project. This series of workshops, appropriate for high school students, will be produced at WVIZ, beginning on April 13, 1999. Workshops are planned in this order, titles as follow:

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Two Forms of Electronic Communications
Getting More Users on a Single Telecommunications System
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